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ABSTRACT

A study investigated the relationship between selected anthropometric variables and of numerous anaerobic power tests with measures obtained on an isokinetic dynamometer. Thirty-one male college students performed several anaerobic power tests, including: the vertical jump using the Lewis formula; the Margaria-Kalamen stair climb test; the Wingate maximun anaerobic capacity and peak power test; the Cybex II isokinetic measures for knee extension and ankle plantar flexion; the 40-yard dash; and the standing long jump. Principal factor analysis and rotation using the varimax criterion were used to identify significant correlations. Results showed no single factor emerged and that unrelated aspects existed among these tests and that they were not measuring similar qualities. It is suggested that anaerobic tests that are used to evaluate anaerobic power be performed as specifically as the skill being tested. (Author/CB)

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Factor Analysis of Various Anaerobic Power Tests

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Abstract

Factor Analysis of Various Anaerobic Power Tests

There are numerous field and laboratory anaerobic power tests used by physical educators, coaches, trainers, and researchers to predict an individual's anaerobic power. Although a large number of these tests exist, no one single best test or anthropometric measure exists which can predict anaerobic power. This study used thirty-one college aged males in order to identify the single best test as well as correlate various antropometric and isokinetic measures with various anaerobic power tests. The anaerobic power tests used were: the vertical jump using the Lewis formula, the Margaria-Kalamen stair climb test, the Wingate maximum anaerobic capacity and peak power test, the Cybex II isokinetic measures for knee extension and ankle plantarflexion at 180 and 240 deg/second, the 40 yard dash, and the standing long jump.

Significant correlations at the $p<.001$ were used in principal factor analysis and then rotated using the varimax criterion. Results showed no single factor emerged. Results also showed that unrelated aspects exist among these tests and that they are not measuring similar qualities. It is suggested that anaerobic tests which are used to evaluate anaerobic power be performed as specifically as the skill being tested.

Introduction

A primary factor in athletic success is the ability of the muscle to generate a high explosive force. This functional capability is an external manifestation of the muscle to develop great amounts of tension very quickly, ultimately generating high speed movements. There does not seem to be one single best muscular performance test to evaluate muscular anaerobic power output although numerous tests do exist (4, 12, 18, 23, 24, 28, 32, 33)

Anaerobic performances which principally involve short bursts of heavy exercise, such as sprinting and jumping, depend on high energy phosphate stores in the muscle. The ability to utilize these stores very quickly may be considered anaerobic power. This is the capability of a muscle to generate maximum force in the shortest possible time. What may differentiate individuals in their power production is that the anaerobic type athlete may either have a greater muscle mass or more fast twitch fibers which have a higher ATP-PC enzymatic activity (6).

Fiber type analyses which generally show a greater fast twitch percentage for the anaerobic type athlete (22) should not be replaced by the practice of a functional evaluation of individuals. Fiber-typing is sometimes unreliable and unable to provide information on the recruitment pattern of muscle fibers during anaerobic power events(6). Numerous studies have investigated anaerobic power production on various athletes

with different functional tests (1, 4, 9, 12, 18, 22, 24, 27, 31, 32, 33, 34). The Margaria-Kalamen test, vertical jump, vertical power jump, standing broad jump, and the 40 yard dash have been evaluated for their ability to generate anaerobic power and it was found that the vertical jump, the standing broad jump and the 40 yard dash were associated with a speed component while the vertical power jump and the Margaria-Kalamen test were associated with a mass component. It was felt that these tests could not be used interchangeably as anaerobic power tests when evaluating subjects (4).

The Wingate Anaerobic test is a reliable test to determine one's maximal anaerobic power and capacity (18, 33). This particular test assigns resistance according to body weight (75 g/kg body weight). The data used to obtain this resistance setting was obtained on young subjects(2). More recent studies have questioned whether such a resistance elicits the highest maximal power outputs in adults (13, 26).

Isokinetic exercise testing has been shown to significantly correlate the percent of fast twitch muscle fibers with fast contractile speeds (r=.50)(34).

The development of maximal muscular power output regarding athletic performance situations has been found to be best simulated with isokinetic methods (15). Maximal power by means of an isokinetic test was significantly correlated (r=.88) with the height of the vertical jump(27).

A moderate relationship had been found between the vertical jump and isokinetic power measured at angular velocities of 180 deg/sec (r=.64) and 240 deg/sec (r=.63). A similar moderate relationship was seen between the Margaria stair-climb test at 180 deg/sec (r=.64) and at 240 deg/sec (r=.68). Lower correlations were found between the standing broad jump and isokinetic power at 180 deg/sec (r=.41) and at 240 deg/sec (r=.52)(11). Other investigators have found the vertical jump (using the Lewis formula) to be correlated (r=.77) with Olympic weight lifting performance (snatch and clean) and considered it a valuable field test and coaching tool (32).

An anaerobic stair climb test (Margaria-Kalamen) has been used to measure anaerobic work capacity as well as to predict various running performances (31).

The use of anaerobic power tests by physical educators, coaches, trainers, and researchers is quite extensive. Few investigations have reported results in the units of power (Watts) (21) and few have correlated isokinetic measures with anaerobic power tests already in use. Thus, the purpose of this study was to determine the relationship between selected anthropometric variables and of numerous anaerobic power tests with various measures obtained on the Cybex II isokinetic dynanometer. These specific anaerobic power tests included: the vertical jump using the Lewis formula (Watts), the Margaria-Kalamen stair climb test (Watts), the Wingate maximal anaerobic capacity and anaerobic peak power test (Watts), Cybex II isokinetic dynamometer readings for knee extension at 180

deg/second and 240 deg/second (Watts), Cybex II isokinetic measures for ankle plantar flexion at 180 deg/second and 240 deg/second (Watts), the 40 yard dash, and the standing long jump. Another aim of this study was to identify the single best predictor of anaerobic power as is the case in determining maximal oxygen uptake as a measure of aerobic power.

Material and Methods

Thirty-one college aged males participated in this study following their granting informed consent. These subjects were considered physically active since all were involved in some type of vigorous physical activity at least four times per week. Each subject took two days to complete all tests. Upon reporting to the Human Performance Laboratory, the subjects were measured for height and weight. All tests were randomly assigned. Because fatigue could have been a factor during the tests, the Wingate anaerobic bike test and the 40 yard dash were always administered last and on separate days. Sufficient rest was given between trials and between tests in order to insure an adequate recovery.

Anthropometric values (Table 1) were taken of the right and left thigh (ULCIR) and calf (LLCIR) for circumference measures (20). A Gulick anthropometric tape measure was used.

Percent body fat (Table 1) was obtained by means of the hydrostatic weighing technique. Seven to ten trials were obtained before the measure was calculated. Residual volume was estimated from vital capacity measures.

The vertical jump (VJ) was administered according to the procedures described by Fox and Mathews (14). The Lewis formula was used to calculate power in Watts.

The Margaria-Kalamen (M-K) anaerobic power test was administered according to the procedures described by Fox and Mathews (14). The distance of the stair climb was 1.04 meters with a 6 meter runway. Electronic switch pads were placed on the third and ninth step. A Dekan performance timer was used to record the subject's elapsed time from step three to step nine taking three steps at a time. Time was recorded to the nearest 1/1000 second.

The Wingate anaerobic test was administered to determine total power output during the 30 second test (anaerobic capacity)(WAnC) (Watts) and to obtain the maximal anaerobic power measure (peak power)(WAnP) (Watts) which is the highest five second power output during the 30 seconds. This test required the subjects to pedal all out with their legs on a bicycle ergometer for 30 seconds against a resistance determined according to the subject's body weight (18). The bicycle ergometer resistance was set at 75 g/kg body weight and each subject pedalled at their maximum speed for 30 seconds while the number of revolutions were counted. The revolutions were continuously monitored in order to determine at what time interval the maximal power was achieved.

The Cybex II isokinetic dynamometer was used to obtain power measures of the knee extensors and ankle plantar flexors of the dominant leg. Each subject was familiarized on a previous day to the Cybex II prior to any data collection. Each subject performed five maximal knee extensions at 180 deg/second (KnS1) and at 240 deg/second (KnF) in the test position as described in the Cybex test manual (17). Five maximal ankle plantar flexion movements at 180 deg/second (AnS1) and at 240 deg/second (AnF) in the test position described in the Cybex test manual (17) were also performed. Knee extension measures and ankle plantar flexion measures at 180 deg/second were added together (KnAnS1) as were knee extension and ankle plantar flexion at 240 deg/second (KnAnF) in an attempt to combine the isokinetic measures to the actual jumping or running motion. The Cybex II was calibrated before and after each test day. Of the five maximal contractions, the greatest one was chosen and converted into power units (Watts).

The 40 yard dash was performed on a dry asphalt track. All subjects used a standing start and were timed by a hand held stopwatch. Three trials were administered with the best time recorded. Time was recorded to the nearest tenth of a second.

The standing long jump (SLJ) was administered in the Human Performance Laboratory according to the directions in the Physical Fitness Research Digest (28). Subjects were allowed to use their arms and were given three trials with the best jump recorded in centimeters.

All units were converted into power units (Watts) except the 40 yard dash and standing long jump prior to analysis.

A SAS Computer Program was used to obtain the correlations and perform the factor analysis. Correlations which were significant at the .001 level were used in factor analysis. Following principal factor analysis, the rotation method of varimax was utilized to obtain the rotated factor pattern.

Results

Correlations among anthropometric variables and power variables are shown in Table 2. A large number of significant correlations existed at the .001 level of confidence. The highest relationships were among weight and LBW (r=.92), weight and VJ (r=.91), and LBW and VJ (r=.89). Several of the isokinetic measures showed a correlation of .90 or above with each other including: the knee extension at 180 deg/second, the knee extension at 240 deg/second, the combination of knee extension and ankle plantar flexion at 180 deg/second, and the combination of knee extension and ankle plantar flexion at 240 deg/second. Significant relationships ($p<.001$) were found with most all other variables except the SLJ and the 40 yard dash. Anthropometric measures were moderately correlated with most of the power tests. The VJ showed the highest relationship (r=.69 to r=.91) with anthropometric values.

The majority of the interrelationships among the power tests were significant at the $p<.001$ level of confidence. Two variables, the SLJ and the 40 yard dash, were only slightly correlated with the other power tests but were negatively significantly correlated ($r=-.62$) with each other.

Principal factor analysis was performed and then rotated using the varimax criterion (Table 3.). Five distinct factors could be identified meaning that there are five underlying constructs which are accounting for the independent factors.

The first factor loaded on lower extremity explosive isokinetic angular power tests which were performed at a speed of movement of between 180-240 deg/second independent of body weight. Factor one accounted for 27.24% of the variance. The second factor loaded on body size plus explosive isokinetic power movements as well as the VJ. This factor accounted for 25.16% of the variance. The third factor loaded on lower extremity body size and explosive tests which involve lifting the body weight vertically. This factor accounted for 18.67% of the variance. The fourth factor loaded on the Wingate anaerobic bike test. This factor accounted for 15.04% of the variance. The final factor loaded on power tests involving explosive horizontal movements such as the SLJ and the 40 yard dash. This factor accounted for 13.89% of the variance.

Discussion

These findings agree with other research (4, 25) that there is no one single anaerobic power test which can be used to measure anaerobic power as compared to maximum oxygen uptake which is used to obtain aerobic power. Factor analysis, when applied to numerous field and laboratory anaerobic power tests, showed that unrelated aspects exist among these tests and that they are not measuring similar qualities.

All anaerobic power tests utilized in this study involved quick explosive movements for a short period of time, i.e., all lasting from less than 1 second to 30 seconds. Some of these tests involved supported body weight while others involved quick explosive movements horizontally and some vertically where the body weight must be supported.

Numerous studies suggest that anaerobic power tests can be used to predict a specific performance (30, 32). The VJ has been shown to be a valuable tool in predicting olympic weightlifting performance(32). Perrine (27) found peak power output on an isokinetic device had a relatively high correlation (r=.88) with the VJ whereas the present study found isokinetic measures and the VJ loaded on the same factor.

Some investigators(14, 19) suggested that the 50 yard dash could substitute for the M-K stair climb test as an anaerobic power test. This seems to be unfounded since in the present study and others(4) found these two tests do not load on the same factor.

Considine (7) used factor analysis with various power tests and found that three factors emerged: distance, time (speed), and a composite power measure where subjects' weight and time in air while performing the VJ is all accounted for.

The measurement of maximum arm power as found on a Biokinetic swim bench was found to be closely related to the performance of a 25 yard swim(8, 30). This suggests that laboratory tests used to measure power should be as specific as possible.

The present study, however does not support the findings of Davies et al. (10), who reported a close association existed between power output while cycling for a few seconds with the vertical jump. The present study does support Bosco et al. (5) findings that the vertical jump, a modified Wingate test and the Margaria test may all be suitable for measuring anaerobic power but are not suitable for evaluation of specific performance tasks.

Although all tests used in the present study are testing the energy pathways which are predominantly anaerobic, there seems to be no one single test which can be used to measure anaerobic power. Of the five factors found in the present study no one factor emerged, therefore, the only tests which overlapped are those within each factor. The factors which did emerge suggest that the power tests within each factor identified specific similar traits and can be substituted for each other. The anaerobic tests used to evaluate anaerobic

power must be performed as specifically as the skill being tested. Therefore, care must be utilized when testing an individual's anaerobic power. If a performance skill is to be tested then the time of event, the body size, the speed of movement, the direction of the task i.e., vertical or horizontal, and whether the task is weight bearing or non-weight bearing must be accounted for when attempting to test the specific anaerobic power of an individual.

Table 1 - Mean values and standard deviations of subjects anthropometric values (n=31)

	X	SD
Age (years)	21.35	2.51
Height (cm)	176.90	7.67
Weight (kg)	73.40	10.57
Lean Body Weight (kg)	62.44	8.73
Percent Fat (%)	14.74	4.91
Upper Leg Circumference (cm)	57.12	3.76
Lower Leg Circumference (cm)	37.12	2.70

Table 2. - Correlation coefficients among all variables (n=31)

Correlation coefficients

Var.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.Ht(cm)	.75	.84	-.16	.44	.57	.64	.10	.27	.44	.50	.74	.71	.41	.36	.71	.68	.71
2. Wt (kg)		.92	.25	.74	.67	.67	.37	.08	.50	.66	.67	.71	.57	.50	.71	.72	.91
3. LBW (kg)			-.15	.61	.62	.77	.17	.28	.59	.68	.70	.74	.47	.42	.70	.73	.89
4. PFAT (%)				.35	.14	-.23	.50	-.46	-.17	-.01	-.06	-.06	.27	.22	.05	.01	.09
5. ULCIR (cm)					.72	.53	.18	.01	.45	.53	.41	.46	.43	.23	.47	.44	.69
6. LLCIR (cm)						.59	.11	.32	.40	.52	.51	.61	.60	.45	.60	.63	.72
7. Margaria-Kalamen(M-K)							-.28	.50	.63	.73	.59	.64	.35	.18	.57	.58	.79
8. 40 yard DASH (sec)								-.62	-.20	-.10	-.06	-.06	.11	.23	-.01	.02	.06
9. Standing Long Jump (cm)									.27	.35	.38	.41	.21	.20	.36	.40	.40
10. Wingate Anaerobic Capacity (WAnC)(W)										.77	.52	.58	.31	.11	.50	.50	.64
11. Wingate Anaerobic Power (WAnP)(W)											.62	.66	.56	.42	.67	.66	.78
12. Knee Extension (180 deg/sec)(W)												.90	.55	.54	.96	.90	.78
13. Knee Extension (240 deg/sec)(W)													.60	.52	.90	.97	.81
14. Ankle Plantar Flexion (180 deg/sec)(W)														.83	.77	.73	.59
15. Ankle Plantar Flexion (240 deg/sec)(W)															.70	.71	.49
16. Knee Ankle Combo. (180 deg/sec)(W)																.94	.80
17. Knee Ankle Combo. (240 deg/sec)(W)																	.81
18. Vertical Jump (W)																	

r = .34 significant at p<.05

r = .55 significant at p<.001

Table 3. Varimax rotated factor matrix (n=31)

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	h*
Height (cm)	.243	.806	.305	.123	-.089	.825
Weight (kg)	.326	.607	.570	.295	.279	.964
LBW (kg)	.215	.760	.479	.287	-.029	.936
ULCIR (cm)	.164	.208	.716	.329	.237	.747
LLCIR (cm)	.402	.277	.684	.118	-.041	.722
M-K (W)	.117	.445	.535	.419	-.386	.822
40 Yd. DASH(sec)	.059	.178	.085	-.173	.788	.694
SLJ (cm)	.251	.131	.173	.069	-.766	.701
WAnC (W)	.083	.267	.263	.761	-.187	.762
WAnP (W)	.358	.248	.392	.651	-.137	.787
KNSL (W)	.580	.639	.063	.373	-.141	.908
KNF (W)	.579	.590	.169	.399	-.170	.901
ANSL (W)	.825	.075	.333	.156	.072	.826
ANF (W)	.862	.156	.149	-.053	.110	.805
KNANSL (W)	.750	.450	.172	.336	-.082	.959
KNANF (W)	.737	.527	.182	.305	-.110	.968
PFAT (%)	.225	-.236	.120	-.005	.644	.561
VJ (W)	.408	.513	.568	.419	-.054	.930
% variance accounted for	27.24	25.16	18.67	15.04	13.89	

*h = communality

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